DOCUMENT RESUME

ED 254 713 CE 040 989

TITLE	Stationary Engineers Apprenticeship. Related Training Modules. 19.1-19.2 Air Compressors.
INSTITUTION	Lane Community Coll., Eugene, Oreg.
SPONS AGENCY	Oregon State Dept. of Education, Salem.
PUB DATE	[82]
NOTE	45p.; For related documents, see CE 040 971-990. Many of the modules are duplicated in CE 041 003.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Apprenticeships; Behavioral Objectives; Energy; Energy Occupations; Equipment Maintenance; *Equipment Utilization; Job Skills; Job Training; Learning Modules; Postsecondary Education; *Power Technology; *Trade and Industrial Education
IDENTIFIERS	*Air Compressors; *Stationary Engineering

ABSTRACT

This learning module, one in a series of 20 related training modules for apprentice stationary engineers, deals with air compressors. Addressed in the individual instructional packages included in the module are types of air compressors and the maintenance and operation of air compressors. Each instructional package in the module contains some or all of the following: a lesson goal, performance indicators, a study guide, a vocabulary list, an introduction, instructional text, an assignment, a job sheet, a self-assessment activity, a post-assessment instrument, answers to the post-assessment instrument, and a list of recommended supplementary references. (MN)

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APPRENTICESHIP

STATIONARY ENGINEERS

RELATED TRAINING MODULES

19.1 - 19.2 AIR COMPRESSORS

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APPRENTICESHIP

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STATIONARY ENGINEER
SUPPLEMENTARY REFERENCE DIRECTORY

Note: All reference packets are numbered on the upper right-hand corner of the respective cover page.

Supplementary Packet #	Description	Related Training Module
12.1	Correspondence Course, Lecture 1, Sec. 2, Steam Generators, Types of Boilers I, S.A.I.T., Calgary, Alberta, Canada	12.1 Boilers, Fire Tube Type
12.2	Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Types of Boilers II, S.A.I.T., Calgary, Alberta, Canada	12.2 Boilers, Water Tube Type
12.3	Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Boiler Construction & Erection, S.A.I.T., Calgary, Alberta, Canada	12.3 Boilers, Construction
12.4	Correspondence Course, Lecture 4, Sec. 2, Steam Generators, Boiler Fittings II, S.A.I.T., Calgary, Alberta, Canada	12.4 Boilers, Fittings
12.4	Corresondence Course, Lecture 4, Sec. 2, Steam Generators, Boiler Fitting I, S.A.I.T., Calgary, Alberta, Canada	12.4 Boilers, Fittings
12.5	Correspondence Course, Lecture 10, Sec. 2, Steam Generation, Boiler Operation, Maintenance, Inspection, S.A.I.T., Calgary, Alberta, Canada	12.5 Boilers, Operation
12.7	Correspondence Course, Lecture 3, Sec. 2, Steam Generation, Boiler Details, S.A.I.T., Calgary, Alberta, Canada	12.7 Boilers Heat Recovery Systems
12.8	Refer to reference packet 14.3/12.8	
		PUMPS
13.1 13.2 13.4 13.6 13.7	Correspondence Course, Lecture 9, Sec. 2, Steam Generator, Power Plant Pumps, S.A.I.T., Calgary, Alberta, Canada	13.1 Types & Classification 13.2 Applications 13.4 Calculating Heat & Flow 13.6 Monitoring & Troubleshooting 13.7 Maintenance
13.3 13.5	Correspondence Course, Lecture 6, Sec. 3, Steam Generators, Pumps, S.A.I.T., Calgary, Alberta, Canada	13.3 Construction 13.5 Operation

Supplementary Packet #	Description	Related Training Module
14.3 12.8	Correspondence Course, Lecture 6, Section 3, Steam Generators, Steam Generator Controls, S.A.I.T., Calgary, Alberta, Canada	14.3 Steam, Transport 12.8 Boilers, Instruments & Controls
14.4	Correspondence Course, Lecture 11, Section 2, Steam Generators, Piping II, S.A.I.T., Calgary, Alberta, Canada	14.4 Steam, Purification
15.1	Correspondence Course, Lecture 1, Sec. 4, Prime Movers & Auxiliaries, Steam Turbines, S.A.I.T., Calgary, Alberta, Canada	15.1 Steam Turbines, Types
15.2	Correspondence Course, Lecture 4, Sec. 3, Prime Movers, Steam Turbines I, S.A.I.T., Calgary, Alberta, Canada	15.2 Steam Turbines, Components
15.3	Correspondence Course, Lecture 2, Sec. 4, Prime Movers & Auxiliaries, Steam Turbine Auxiliaries, S.A.I.T., Calgary, Alberta, Canada	15.3 Steam Turbines, Auxiliaries
15.4	Correspondence Course, Lecture 6, Sec. 3, Prime Movers, Steam Turbine Operation & Maintenance, S.A.I.T., Calgary, Alberta, Canada	15.4 Steam Turbines, Operation & Maintenance
15.5	Correspondence Course, Lecture 8, Sec. 3, Prime Movers, Gas Turbines, S.A.I.T., Calgary, Alberta, Canada	15.5 Gas Turbines
16.2	Boilers Fired with Wood and Bark Residues, D.D. Junge, F.R.L., O.S.U. 1975	16.2 Combustion Types of Fuel
16.2	Correspondence Course, Lecture 5, Sec. 2, Steam Generators, Fuel Combustion, S.A.I.T., Calgary, Alberta, Canada	16.2 Combustion Types of Fuel
16.3	Correspondence Course, Lecture 5, Sec. 2, Plant Services, Fuel & Combustion, S.A.I.T., Calgary, Alberta, Canada	16.3 Combustion, Air & Fuel Gases
17.1	Correspondence Course, Lecture 12, Sec. 3, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.1 Feed Water, Types & Operation
17.2	Correspondence Course, Lecture 12, Sec. 2, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.2 Feed Water, Water Treatments

Supplementary Packet #	Description	Related Training Module
17.3	Correspondence Course, Lecture 7, Sec. 2, Steam Generators, Boiler Feed Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.3 Feed Water, Testing
18.1	Correspondence Course, Lecture 2, Sec. 5, Electricity, Direct Current Machines, S.A.I.T., Calgary, Alberta, Canada	18.1 Generators, Types & Construction
18.1 18.2	Correspondence Course, Lecture 4, Sec. 5, Electricity, Alternating Current Generators, S.A.I.T., Calgary, Alberta, Canada	18.1 Generators, Types & Construction 18.2 Generators, Operation
19.1	Corrspondence Course, Lecture 5, Sec. 4, Prime Movers & Auxiliaries, Air Compressor I, S.A.I.T., Calgary, Alberta, Canada	19.1 Air Compressors, Types
19.1 19.2	Correspondence Course, Lecture 6, Sec. 4, Prime Movers & Auxiliaries, Air Compressors II, S.A.I.T., Calgary, Alberta, Canada	19.1 Air Compressors, Types 19.2 Air Compressors, Operation & Maintenance
20.1	Basic Electronics, Power Transformers, EL-BE-51	20.1 Transformers
21.1	Correspondence Course, Lecture 7, Sec. 5, Electricity, Switchgear & Circuit, Protective Equipment, S.A.I.T., Calgary, Alberta, Canada	21.1 Circuit Protection
22.1	Correspondence Course, Lecture 10, Sec. 3, Prime Movers, Power Plant Erection & Installation, S.A.I.T., Calgary, Alberta, Canada	22.1 Installation Foundations

RECOMMENDATIONS FOR USING TRAINING MODULES

The following pages list modules and their corresponding numbers for this particular apprenticeship trade. As related training classroom hours vary for different reasons throughout the state, we recommend that the individual apprenticeship committees divide the total packets to fit their individual class schedules.

There are over 130 modules available. Apprentices can complete the whole set by the end of their indentured apprenticeships. Some apprentices may already have knowledge and skills that are covered in particular modules. In those cases, perhaps credit could be granted for those subjects, allowing apprentcies to advance to the remaining modules.

We suggest the the apprenticeship instructors assign the modules in numerical order to make this learning tool most effective.

SUPPLEMENTARY INFORMATION

ON CASSETTE TAPES

Tape 1: Fire Tube Boilers - Water Tube Boilers and Boiler Manholes and Safety Precautions

Tape 2: Boiler Fittings, Valves, Injectors, Pumps and Steam Traps

Tape 3: Combustion, Boiler Care and Heat Transfer and Feed Water Types

Tape 4: Boiler Safety and Steam Turbines

NOTE: The above cassette tapes are intended as additional reference material for the respective modules as indicated, and not designated as a required assignment.

19.1

AIR COMPRESSORS -- TYPES

Goal:

The apprentice will be able to describe air compressors and their construction.

Performance Indicators:

1. Describe positive displacement compressors.
2. Describe dynamic type compressors.
3. Describe construction of compressor parts.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary

* Axial thrust
* Centrifugal
* Double acting
* Dynamic type
* Lobe type
* Positive displacement type
* Reciprocating
* Rotary type
* Screw type
* Single acting
* Sliding vane type

Introduction

Compressed air has mnay uses around industrial sites. It is used for painting, cleaning, pneumatic tool operation, soot blowing and many other purposes. Air compressors are an integral part of most power plants. Often they are driven by steam from the plant or a steam driven turbine.

Compressors come in many designs and sizes. A size and design is selected according to the work to be performed by the use of compressed air. A plant operator must be able to select the appropriate compressor for their location. A basic understanding of the various types of compressors available will help the operator to make better choices.

Information

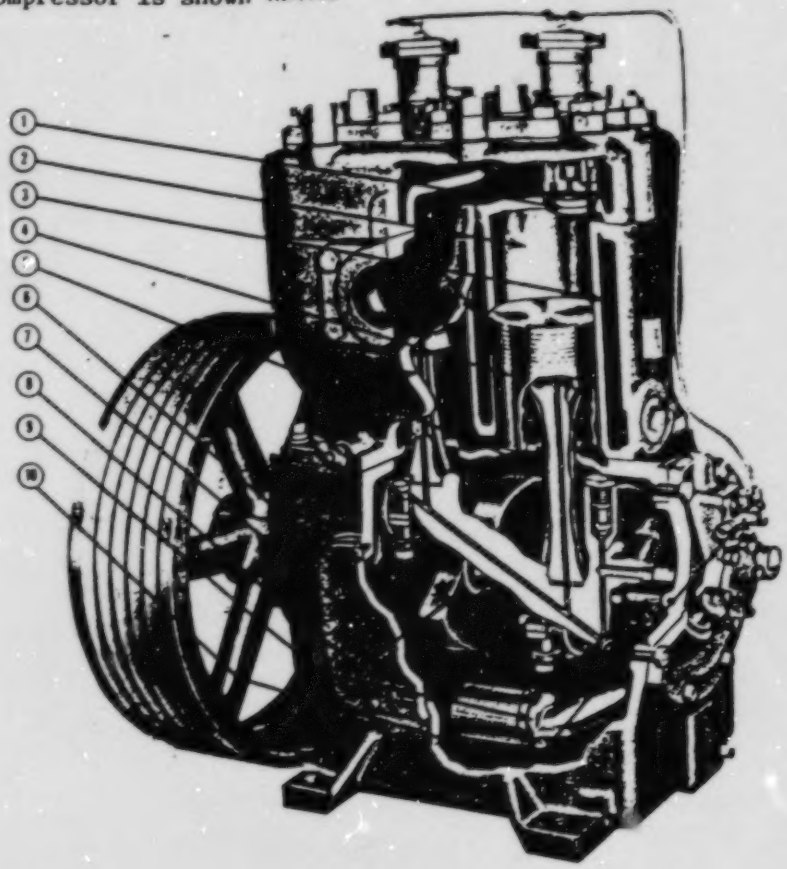
Air compressors are of two basic types:

* Positive displacement
* Dynamic

Positive Displacement Compressors

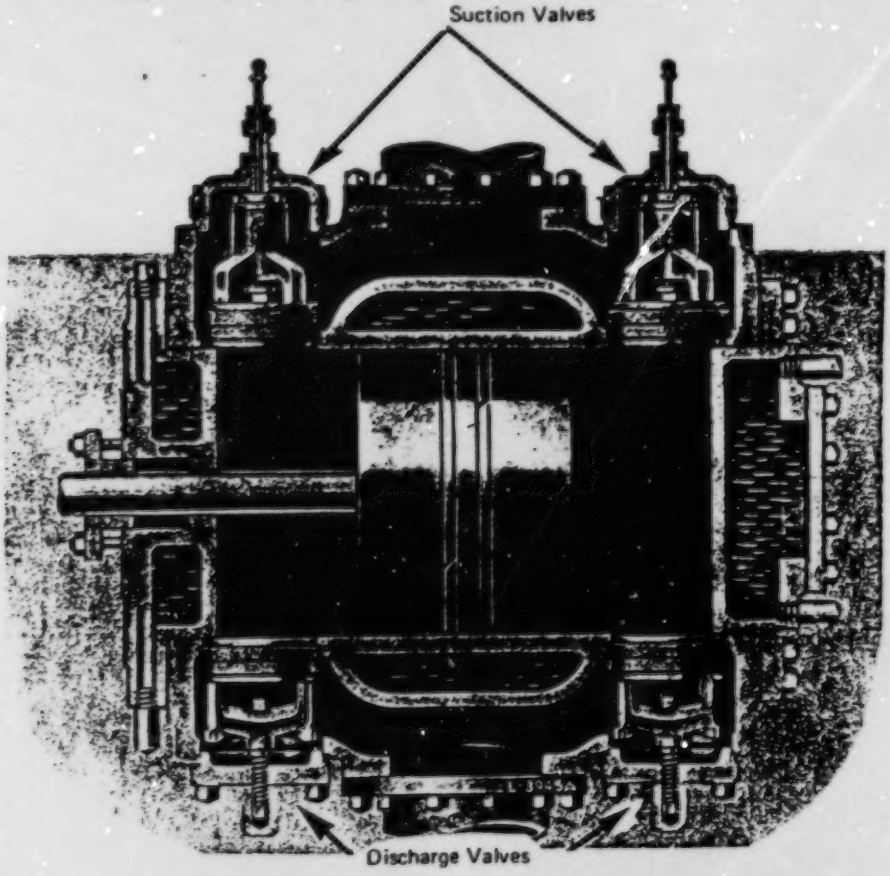
A positive displacement compressor is one that compresses a definite amount of air for each stroke or turn that it makes. The positive displacement compressor may be a reciprocating type which uses a cylinder and piston arrangement or a rotary type that uses vanes or lobes to compress the air. Reciprocating compressors may be a single acting in which the compression occurs at one end of the cylinder. A double acting type compresses at both ends of the cylinder. A single acting reciprocating compressor is shown below.

1. plate type valve
2. cylinder
3. cylinder water jacket
4. automotive type piston
5. connecting rod.
6. crankcase
7. crankcase door
8. crankshaft counterweight
9. oil screen
10. low oil pressure alarm



Information

A double acting reciprocating compressor is shown.

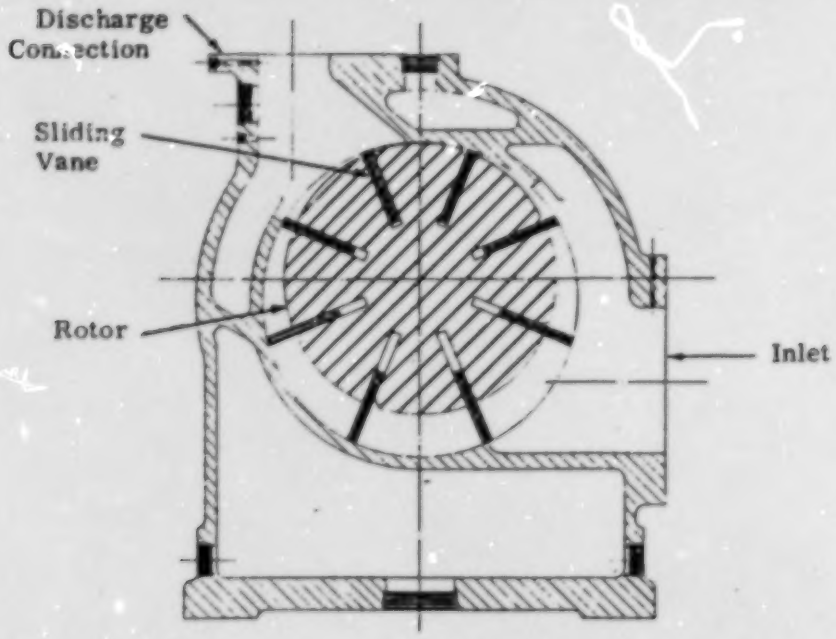


Rotary compressors are positive displacement types. They can be further classified as:

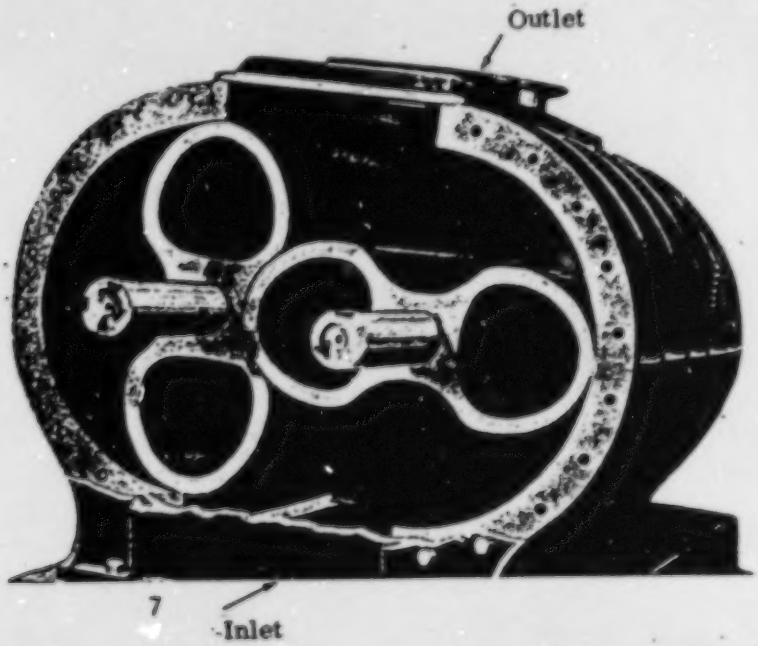
* Sliding vane type
* Lobe type
* Screw type

The sliding vane type has vanes that fit into radial slots on the rotor. As the rotor turns, the vanes are tossed outward by centrifugal force. Air is trapped and squeezed as the vanes move toward the outlet.

Information

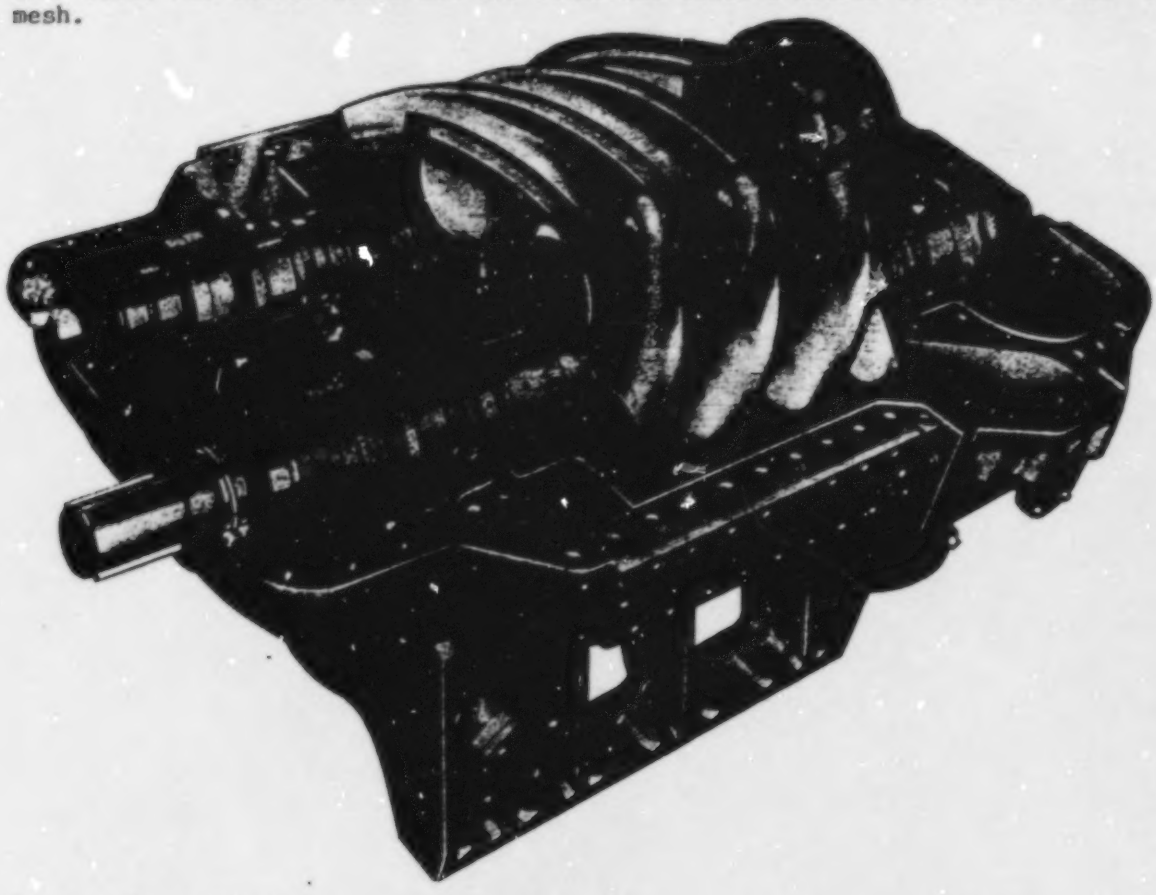


The rotary lobe compressor has lobe shaped impellers that turn in opposite directions. The interface between the lobes squeezes the air as it moves from inlet to outlet.



Information

A rotary screw compressor uses two screw shaped rotors that mesh as they turn. One rotor has convex lobes and the other has concave flutes that allow them to mesh.



Dynamic Compressors

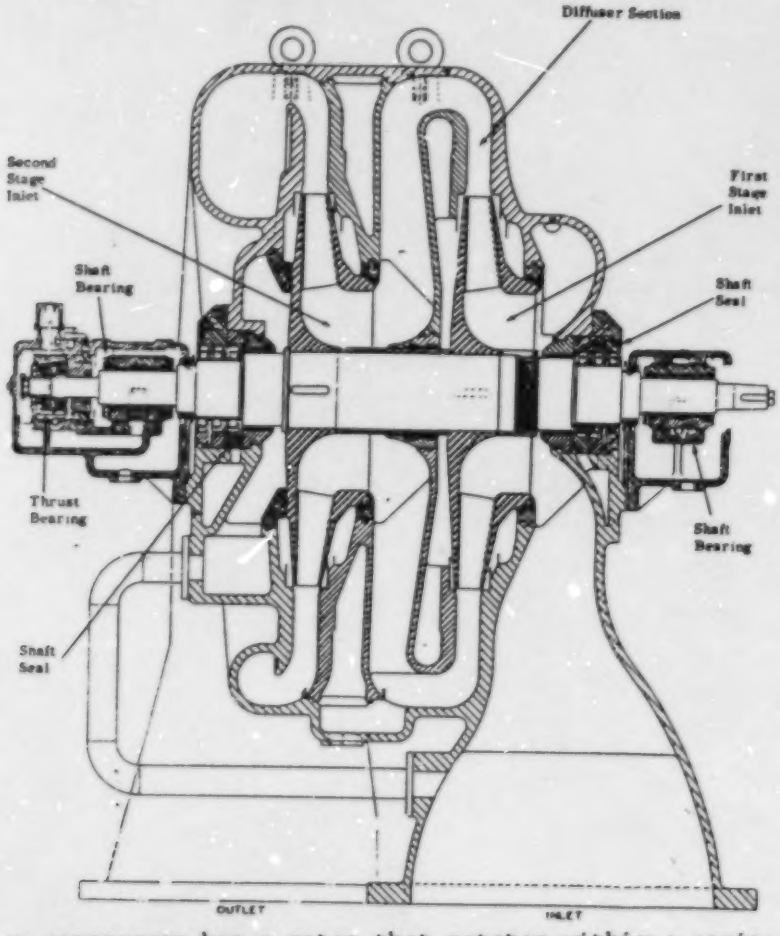
A dynamic compressor increases the velocity of the air and then converts that velocity into pressure. The dynamic compressor is subdivided into two types.

* Centrifugal
* Axial flow

The centrifugal compressor draws air into the eye of the impeller and discharges

Information

it from the outer rim of the impeller. The casing has attached vanes that diffuse the air and convert it to pressure. The air is then forced through a volute shaped casing to further compress it. This compressor operates on centrifugal action of the impeller.



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The axial flow compressor has a rotor that rotates within a casing. The rotor has moving blades that move between fixed blades attached to the casing. Air is moved between the two sets of blades. Its velocity is converted to pressure. It is constructed much like a turbine.

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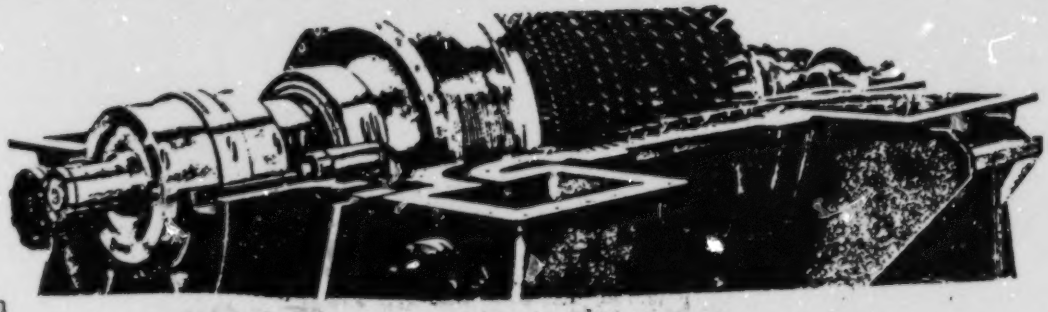
Information



Construction

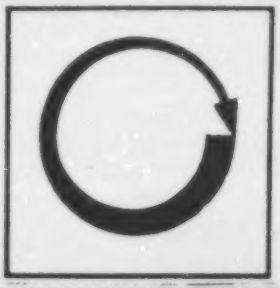
Compressors are often driven by exhaust steam from steam generation plants. In that case, a reciprocating steam engine is used to drive the compressor. It is usually mounted on a common base with the steam engine. In other cases, a steam turbine may be used to drive the compressor. The compressor parts are made of materials that will withstand the pressures of each situation. The parts of a reciprocating compressor and the materials used in construction are:

* Cylinders -- cast iron for pressures up to 1000 kPA. Cast steel for pressures up to 6900 kPA and forged steel for pressures beyond 6900 kPA.
* Pistons -- aluminum, cast iron or steel
* Crossheads -- steel
* Crankshafts -- forged steel
* Valves -- alloy steel

Dynamic compressors of the centrifugal type are driven by gasoline engines, electric motors, steam turbines and gas turbines. The impellers of a centrifugal compressor are steel castings, forging or welded construction. Shafts are forged steel and casings are made of forged steel.

Axial flow compressors are driven by steam or gas turbines. The casings are made of cast steel or cast iron. Their rotor shafts are made of forged steel. The axial flow compressor must be constructed to withstand the axial thrust of the rotating blades. Axial flow compressors are very much like a reaction turbine in the way they are constructed. The problems of axial thrust are the same as that encountered with the turbine.

Assignment



* Read the supplementary reference material and study the photographs and illustrations carefully.
* Complete the job sheet.
* Complete the self-assessment and check answers.
* Complete the post-assessment and have insturctor check answers.

Job Sheet

OBSERVE AIR COMPRESSORS AT YOUR PLANT SITE

* What kind of air compressors do you see? Classify them.

* How are they driven?

* How much capacity (pressure) can they deliver?

* How is air used at this plant?

Self Assessment

1. What is a positive displacement compressor?

2. List two types of positive displacement compressors.

3. What does double acting mean?

4. List three types of rotary compressors.

5. List two types of dynamic compressors.

6. What is a dynamic compressor?

7. For pressures beyond 6900 kPA, what material should be used for cylinders?

8. What is usually used to drive axial flow compressors?

9. Which compressor is constructed like a turbine?

10. Which type of compressor has an impeller that draws air in through its eye and discharges it from its rim?

Self Assessment Answers

1. One that compresses a definite amount of air at each stroke or turn.
2. Reciprocating, rotary
3. Compresses air at each end of the cylinder.
4. Sliding vane, lobe, screw
5. Centrifugal, axial flow
6. One that increases velocity of air and then converts velocity to pressure.
7. Forged steel
8. Steam turbines, gas turbines
9. Axial flow
10. Centrifugal

Post Assessment

Match the following terms and phrases.

____ 1.	Positive displacement	A. A type of rotary compressor.
____ 2.	Dynamic	B. A type of dynamic compressor with an impeller.
____ 3.	Double acting	C. Used for cylinders of pressures of 1000 - 6900 kPA.
____ 4.	Sliding vane	D. A compressor that compresses a definite amount of air at each stroke or turn.
____ 5.	Axial flow	E. Usually made of forged steel.
____ 6.	Cast steel	F. A problem in axial flow compression.
____ 7.	Canary	G. Constructed much like a reaction turbine.
____ 8.	Axial thrust	H. A compressor that converts velocity of air to pressure.
____ 9.	Shafts	I. A small yellow bird.
____ 10.	Centrifugal	J. Compresses at each end of the cylinder.

Instructor Post Assessment Answers

D 1.

H 2.

J 3.

A 4.

G 5.

C 6.

I 7.

F 8.

E 9.

B 10.

Supplementary References

* Correspondence Courses. Lectures 5 and 6. Section 4, Third Class. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.

19.2

AIR COMPRESSORS -- OPERATION AND MAINTENANCE

Goal:

The apprentice will be able to describe the operation and maintenance of air compressors.

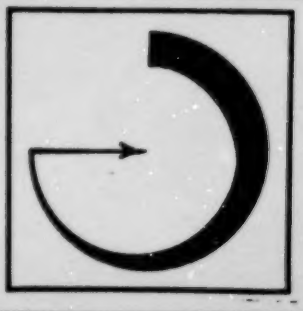
Performance Indicators:

1. Describe cooling.
2. Describe air receivers.
3. Describe air filtering.
4. Describe regulating.
5. Describe surging.
6. Describe lubrication.
7. Describe maintenance.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Aftercooler
* Air filter
* Air receiver
* Cooling
* Intercooler
* Regulation
* Surging
* Throttling governor
* Unloading device

Introduction

Air compressors must be operated in a manner that is safe and efficient in the production of air. As air is compressed to its maximum pressure, a lot of heat is developed. The heat must be removed from the working parts of the compressor. Cooling becomes a critical factor in air compression.

The heat can cause oils to be converted into carbon deposits. Carbon deposits and their oil vapors combine with air mixtures to make explosions. So oiling of compressors must be done with a great deal of understanding and common sense. Most maintenance efforts are directed toward keeping the compressor cooled down.

Information

Cooling

Many small compressors are cooled by air pulled in from the atmosphere. Most large compressors are water cooled. Water is routed through the cylinder head in much the same way as an internal combustion engine is cooled. The water travels through water chambers that have been cast into the cylinder block and head. Circulating pumps move the water so that the heat of the cylinder is moved out and cool water is available to absorb heat as it develops. As the water collects heat, it should be cooled by circulating it through a cooling pond or tower before it is returned to the cylinder.

After compression of the air, it is cooled further before being used. The cooling of air after compression is done in two steps. The first step is called intercooling. Intercoolers are waterfilled tubes over which the compressed air passes. When compression is done by stages to get highly compressed air, intercooling is practiced between stages. The intercooler shell must have a drain to remove water that condenses during the cooling of the warm air.

A second step in air cooling is done in the aftercooler. After the compression is completed, air is cooled some more before being delivered to the user site. The aftercooler is a shell and tube structure that contains the water. The air flows over and near the waterfilled tubes and is cooled. The aftercooler must also be provided with a drain.

Air Receivers

An air receiver is necessary for maintaining a reserve air supply. The receiver should be fitted with a pressure gauge, safety valve and a drain cock. The line to the receiver should also have a safety valve to prevent damage from operating the compressor when the line shut off valve is closed.

Air Filters

All atmospheric air that enters the compressor should be filtered. Filtering removes foreign matter that can be abrasive to the compressor cylinder and other parts. A suction air filter should be used on openings that intake air.

Regulation

An automatic system should be installed for controlling the output of the compressor. A variable speed control system helps maintain a constant supply of air in the receiver. The system is controlled by a throttling governor which

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speeds up the compressor when air pressure drops in the receiver. As the air pressure reaches its maximum point, the governor slows down the air compressor. Another system of constant speed control uses an unloading device to regulate air flow to the receiver.

Surging

Dynamic type compressors have problems with surging. Due to changes in volume and pressure, the air sets up a reverse flow that causes shock waves. This surging of air can damage seals, blading and other parts of the compressor. Surging can be prevented by keeping the compressor capacity above surge limits. An automatic blow-off valve can be used to discharge the flow to avoid surging.

Lubrication

Most reciprocating compressors have built in lubrication systems of the pressure or splash types. Dynamic type compressors may have a pressure lubrication system or be oiled by ring and chain oilers.

Maintenance

Each manufacturer provides specific instructions for the maintenance of their compressors. These instructions should be carefully followed. A few maintenance points should be emphasized.

* Do not over-oil or spill oil. This causes carbon formation when heated. Carbon deposits can cause explosions.
* Use only recommended oil for the cooling system.
* Always turn on cooling water before starting the compression.
* Clean scale deposits from water jackets and intercooler pipe.
* Repair leaky discharge valves.
* Clean air filters regularly.

Air compressors must be maintained to minimize the heat of compression. Routine maintenance that will prevent the development of carbon deposits will add equipment life and be much safer to the operator.

Assignment

* Read pages 8 - 19 in supplementary reference.
* Complete the job sheet.
* Complete the self-assessment and check answers.
* Complete the post-assessment and have the instructor check your answers.

Job Sheet

COMPLETE A MAINTENANCE CHECK ON AN AIR COMPRESSOR

* Obtain the manufacturers manual on the air compressor.
* Conduct routine maintenance check following the manufacturers directions.
* Observe
  - Is there evidence of over-oiling or oil spills?
  - Location of safety valves and shut-off valves.
  - Location of intercooler, aftercooler and receiver.
  - Type of compressor, size, rating.

Self Assessment

1. How are large compressors usually cooled?

2. How is water moved through the cylinder heads?

3. The first step in the cooling of compressed air is called _____.

4. The second step in cooling of compressed air is called _____.

5. Where does the air go after being cooled?

6. Why should air be filtered before it enters a compressor?

7. A variable speed control system is controlled by a _____ _____.

8. A reverse flow of air that causes shock waves in the air compression system is called _____.

9. What are the results of over-oiling or spilling oil in the air compression?

10. Why should the line from compressor to receiver have a safety valve?

Self Assessment Answers

1. Water cooled
2. Circulating pumps
3. Intercooling
4. Aftercooling
5. Air receiver
6. Dirty air is abrasive to the internal parts of the compressor. It causes excess wear on cylinders, valves, etc.
7. Throttling and governor
8. Surging
9. Oil and heat create carbon deposits. Carbon deposits and air can cause explosions.
10. If it has a shut-off valve, it should also have a safety valve. The safety valve protects the pump from overpressure when the shut-off valve has not been opened.

Post Assessment

1. Air receiver	A. Controls a variable speed control system.
2. Aftercooler	B. Oiled by pressure system or oil and ring system.
3. Circulating pumps	C. Shock waves caused by reverse flow of air in compressor.
4. Filtering	D. Oiled by pressure or splash systems.
5. Throttling governor	E. The second step in cooling air after its compression.
6. Intercooling	F. Caused by oil that has been overheated.
7. Surging	G. Prevents wear due to abrasive action.
8. Dynamic type	H. Should be fitted with a safety valve, pressure gauge and drain cock.
9. Reciprocating type	I. Moves water through cooling system.
10. Carbon deposits	J. The first step in cooling of air and often used between stages of compression.

Instructor Post Assessment Answers

H 1.

E 2.

I 3.

G 4.

A 5.

J 6.

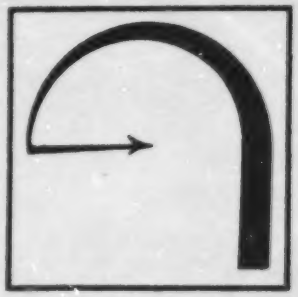
C 7.

B 8.

D 9.

F 10.

Supplementary References



* Correspondence Course. Lecture 6, Section 4, Third Class. Air Compressors. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.